A SURVEY OF BACKCOUNTRY WATER QUALITY IN GREAT SMOKY MOUNTAINS NATIONAL PARK

RESEARCH/RESOURCES MANAGEMENT REPORT No. 10

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
SOUTHEAST REGION

UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS NATIONAL PARK
TWIN CREEKS AREA
GATLINBURG, TENNESSEE 37738

LIBRARY
GREAT SMOKY MOUNTAINS
NATIONAL PARK

The Research/Resources Management Series of the Natural Science and Research Division, National Park Service, Southeast Regional Office, was established as a medium for distributing scientific information originally prepared for park Superintendents, resource management specialists, and other National Park Service personnel in the parks of the Southeast Region. The papers in the Series also contain information potentially useful to other Park Service areas outside the Southeast Region and often benefit independent researchers working in the parks. The Series provides for the retention of research information in the biological, physical, and social sciences and makes possible more complete in-house evaluation of non-refereed research, technical, and consultant reports.

The Research/Resources Management Series is not intended as a substitute for refereed scientific or technical journals. However, when the occasion warrants, a copyrighted journal paper authored by a National Park Service scientist may be reprinted as a Series report in order to meet park informational and disseminative needs. In such cases permission to reprint the copyrighted article is sought. The Series includes:

1. Research reports which directly address resource management problems in the parks.

2. Papers which are primarily literature reviews and/or bibliographies of existing information relative to park resource management problems.

3. Presentations of basic resource inventory data.

4. Reports of contracted scientific research studies which are reprinted due to the demand.

5. Other reports and papers considered compatible to the Series, including approved reprints of copyrighted journal papers and results of applicable university or independent research.

The Series is flexible in format and the degree of editing depends on content.

Research/Resources Management Reports are produced by the Natural Science and Research Division, Southeast Regional Office, in limited quantities. As long as the supply lasts, copies may be obtained from:

Natural Science and Research Division
National Park Service
Southeast Regional Office
75 Spring Street, SW
Atlanta, Georgia 30303

A SURVEY OF BACKCOUNTRY WATER QUALITY

IN GREAT SMOKY MOUNTAINS NATIONAL PARK

Research/Resources Management Report No. 10

December 1976

by

David Silsbee
Williams College
Williamstown, Massachusetts 01267

Linda A. Plastas, Ph.D.
Associate Professor of Chemistry
Montgomery College
Rockville, Maryland 20850

Harold J. Plastas, Ph. D.
Chairman, Department of Chemistry
Montgomery College
Takoma Park, Maryland 20012

U.S. Department of the Interior
National Park Service
Southeast Regional Office
Uplands Field Research Laboratory
Great Smoky Mountains National Park
Gatlinburg, Tennessee 37738

Silsbee, David, Linda A. Plastas and Harold J. Plastas. 1976. A Survey of Backcountry Water Quality in Great Smoky Mountains National Park. U.S. Department of the Interior, National Park Service, NPS-SER Research/Resources Management Report No. 10. 66 pp.

TABLE OF CONTENTS

Summary . . . . . .
Management Recommendations 1
Introduction 8
Methods 9
Results 16
Discussion 22
Acknowledgements 30
References 31
Appendix 32

SUMMARY

Fecal coliform and fecal streptococcus concentrations were analyzed at backcountry water sources. Water sources were found to fall generally into four categories: flowing springs, seepage springs, spring-fed streams, and tributary-fed streams. Flowing springs tended to give consistently low coliform counts. Seepage springs were highly variable, giving both low counts and quite high counts. Small spring-fed streams also tended to be quite variable and gave high counts at times. Larger tributary-fed streams generally gave quite consistent levels of contamination, although somewhat higher than flowing springs. Most of the fecal coliform to fecal streptococcus ratios indicated animal sources of contamination. No significant effects of pit toilets or campsites were found. Fecal coliform and streptococcus counts were also determined in the Cades Cove area. The cattle there were found to be producing levels of contamination in the water far above desirable levels for a natural area in a national park.

MANAGEMENT RECOMMENDATIONS

The most important water quality problem is the lack of visitor and park staff awareness of water quality in the park. Visitors should be conscious of potential sources of contamination. They also need to know how to purify water and how to avoid contaminating it themselves. We suggest the following:

1) The park staff, particularly field and seasonal staff with frequent visitor contact, should understand why there are no approved or developed drinking water sources in the backcountry. To this end we suggest that seasonal staff be given a training handout which discusses water quality in the backcountry and provides the correct responses to the most commonly asked questions. At seasonal training, the sanitarian might be asked to give a short session on water quality in the park, backcountry and otherwise (A sample handout is included in the appendix).

2) All handouts to hikers, trail maps and signs at trail heads should include notices such as PURIFY ALL WATER (This is presently the case, although the information on the official trail map could be expanded). Any programs or publications on hiker safety should include information on drinking water and sanitation.

3) Park staff should not encourage people to drink unpurified water by

   a) extolling the virtues of park water in a visitor program without mentioning that water should be purified,

   b) drinking unpurified water in front of visitors (either on guided walks or in the backcountry camping areas),

   c) by saying they drink the water all the time themselves and it is just fine.

   Legal or public relations problems can be avoided if visitors are made aware that they can become ill from drinking contaminated water.

4) Until further tests indicate the silt and coliform levels have dropped, campers traveling along Abram's Creek should be encouraged to take water from tributaries and purify it, rather than take water from the main branch. The trailheads might be temporarily posted, although a warning from the person issuing the camping permit should suffice in most cases.

One has to assume that some people are going to drink untreated water, whatever they are told. The National Park Service should try to educate as many people as possible. It may take several years to change the present, rather careless patterns of backcountry sanitation. The increased densities of hikers and the presence of large

numbers of novice campers make visitor education the most important way to improve backcountry sanitation.

Aside from removing stock from the vicinity of Abram's Creek, there is probably very little that can be done through maintenance that would clean up backcountry water in the park. The condition of the "seepage springs" could be improved by cutting back around the spring into the slope and adding a wall. However, this would appear as a "safe, maintained" source to the visitors and, therefore, must be avoided. Leaving springs and streams in as natural a state as possible is the most desirable management, from an aesthetic point of view. Park staff should not add wall or pipes without consulting the sanitarian.

Although the data presented here are not very extensive there seems to be little impact of campsites on the water quality below the sites. Contamination is either so low or so irregular that coliform counts (especially when done only once or twice) are probably not a good indicator of campsite overuse or abuse. There was also little evidence that more outhouses are needed, or that they control contmaination of water, although this part of the study needs to be expanded and further sampling done. A well-placed and maintained outhouse can serve to locate wastes in the optimum place, and draw hikers away from drinking water sources. This might also be done by marking a sanitary area away from the main water source.

High-use sites near (or above) springs and small streams are the most liable to contamination and are the best candidates for carefully placed privies.

Placement of campsites, trails and outhouses in relation to water sources may be the most important factor in determining possibility of frequent human contamination. Whenever possible, water sources should be above trails and probable human use areas. In doubtful cases, the sanitarian should be consulted. Wildlife contamination can be partially controlled by keeping the campsites clean of garbage. This is again best attacked through visitor education. Strictly controlling the numbers of campers using a site will tend to improve sanitation. Closing a site temporarily, or restricting use may help avoid problems when the area around the water source is eroding or when wildlife use of the site has become intensive. Vegetation damage and erosion are better indicators of site overuse than monitoring bacteria quality near the site.

The water quality in Abram's Creek needs to be improved as much as possible. The visitors expect "clean, clear mountain streams" for fishing, swimming and wading. The present situation is undesirable from a biological point of view. The high counts, particularly after rains, indicate that the stream is not "cleaning itself" of the excess organic matter added by the cattle.

Inside Cades Cove, an historical area, pure water is not essential, but introduction of manure and silt should be curtailed as much as possible. Below Cades Cove, however, the water enters a natural area, and should be clean enough so that there is no adverse impact on native flora and fauna. Clearly the most effective way of reducing the stream pollution in Abram's Creek would be to reduce the number of cows in Cades Cove. If for reasons of scenic or historic management, public relations, or other pressures, it is necessary to keep substantial numbers of livestock within Cades Cove, proper management of the remaining animals would greatly reduce their impact on the streams.

Since a large number of cattle are presently being removed from Cades Cove (summer 1976), the sanitarian and research staff will run tests and determine if the removal has significantly reduced the problem. Studies of silt and coliform levels can be easily conducted, assuming technicians help.

Water quality can be further improved by completely fencing the cattle out of the streams. At present, many streams are fenced, but the cattle are always allowed an access point for drinking. When the weather is warm the cattle is expensive, but would allow a buffer zone between the pastures and the creeks; possibly gravity-fed piping of water from slighly higher streams could be arranged. If the cattle are to be seen by visitors it is better to fence them out of the woods and creeks in any case. Placing pasture areas near the road, and at

the eastern end of the cove might also help to reduce the problem. If the cattle are for scenic purposes, a small number fenced near the road would be just as visible as a large number allowed to wander into the woods and stream beds. In the future, selected locations can be monitored for silt, coliform, nitrate and other possible contaminants, to determine acceptable numbers and locations of cattle.

As further changes are made in the management of the cove, the water in Abram's Creek should be tested for indications of significant improvement. Coliform counts can be used to locate pollution sources and problem areas.

Suggestions for Further Sampling

Further sampling would be useful both in checking areas not covered in this survey and in extensive monitoring of areas which seem to have problems. A long-term monitoring of Abram's Creek could be very useful in determining the effects of any changes in the locations and sizes of cattle herds as well as fluctuations with weather and water level. The springs along the Appalachian Trail, especially the ones which have produced contaminated samples in this survey, should also be monitored on a longer term basis.

An analysis of the individual streptococcus strains in the fecal streptococcus group might help to determine the source of stream contamination. The presence or absence of certain strains

could be a better indicator of the species involved than the fecal coliform to fecal streptococcus ratio investigated in this study. This would require a much more involved procedure, however, and might not be feasible with the equipment, supplies, and manpower presently available. It would also be subject to the same problems of differential die-off rates, multiple sources of contamination, and indeterminate period of time since deposition of the feces. Still, of it proved possible, it could give an idea as to whether the contamination was from wildlife or human sources, which would be useful if an attempt was made to clean up any streams.

The data presented here does not provide much information on the impact of campsites (with and without outhouses) on streams. It is not clear if pit toilets are necessary and if their placement is always correct. A study of this would probably require intensive sampling of a few sites, since coliform levels fluctuate widely in contaminated sources.

INTRODUCTION

The goals of this preliminary water quality survey were:

1) To investigate methods of water sampling applicable to remotely located water sources such as those at backcountry campsites,
2) To determine where there might be bacteriological water quality problems in the park,
3) To determine the major sources of fecal pollution in the backcountry,
4) To determine how springs and different size streams behave with respect to fecal pollution.

The Millipore membrane filtration method was used to analyze water samples for fecal coliform and fecal streptococcus bacteria. An attempt was made to use the relative numbers of these two types of bacteria to determine the mammalian species responsible for the contamination. Springs and streams were sampled to determine the patterns of contamination in different types of water sources. Streams were sampled above and below developments such as pit toilets, campsites, and trail crossings to try to determine the bacteriological effects of human use of these developments on the water. Areas sampled include the Cades Cove area, the Appalachian Trail, the north side of Mt. LeConte, and the Deep Creek area.

A complete, rather than a referenced description of the methods

is included, so that investigators working on similar problems in the park will know exactly which techniques were used and what modifications were made.

METHODS

The basic method used for bacteria analysis was Millipore membrane filtration as described in Millipore publications (1). Water is pulled through a filter which traps all bacteria larger than .45 mμ. The filter is then placed on a selective growth medium and incubated. Colonies grow directly on the filter and can be counted. At all sample sites more than a mile from the road, water samples were filtered in the field and transported back to the laboratory on a holding medium plate. The holding medium allowed a delay of up to 72 hours between filtering and incubation. This is essential in back-country sampling, as it is frequently not possible to get water samples to an incubator immediately. In the laboratory the filter was transferred to growth media and incubated. Fecal coliform plates were incubated at 44.5°C for 24 hours; fecal strep at 35°C for 48 hours. For sample sites less than a mile from a road, water was carried back to the lab, filtered, and the filter placed directly on growth media and incubated. Sample sizes were either 100 or 200 ml. for samples filtered in the field and ranged from 1 to 100 ml. for samples filtered in the lab. All sampling bottles and sampling equipment were autoclaved before use. Great care was taken to avoid touching

the mouths of the bottles or otherwise introducing extraneous bacteria in the process of sampling.

Media

M-FC Broth was used as a growth medium for fecal coliform. Millipore's (2) directions are as follows:

1) Using a spatula or scoop, weigh out 3.7 grams of dehydrate into a weighing dish on the laboratory balance.
2) Pour out 100 ml (0.1 liter) of distilled water into a clean 100 ml graduated cylinder.
3) Pour out approximately 20 ml of the distilled water from the graduated cylinder into a clean 250 ml screw-cap Erlenmeyer flask without spilling.
4) Empty the contents of the weighing dish carefully into the prepared 250 ml Erlenmeyer flask and swirl to disperse the dehydrate.
5) Pour the remaining contents of the graduated cylinder into the 250 ml Erlenmeyer flask without spilling.
6) Obtain rosolic acid dehydrate from the reagent shelf.
7) Weigh out 1 gram of dehydrated rosolic acid on the laboratory balance according to weighing procedure above.
8) Measure out 100 ml of 0.2 N sodium hydroxide solution into a clean 100 ml graduated cylinder.
9) Pour out approximately 20 ml of sodium hydroxide from the graduated cylinder into a second clean 250 ml screw-cap Erlenmeyer flask without spilling.
10) Carefully empty the contents of the weighing dish (rosolic acid dehydrate) into the second prepared 250 ml. Erlenmeyer flask and swirl to disperse the dehydrate.
11) Pour the remaining contents of the graduated cylinder into the second 250 ml Erlenmeyer flask without spilling. This produces a 1% rosolic acid solution.
12) Pipette out 1 ml of 1% rosolic acid solution.
13) Dispense 1 ml into the flask containing the dissolved M-FC broth.
14) Place the flask, loosely covered, in a boiling water bath.
15) Heat the medium to the boiling point, then remove and cool.
16) Dispense at room temperature, pH should be 7.4.
17) Store unused portion at 2-10^{o}C and discard after 96 hours.

A few slight modifications of Millipore's directions were employed. Refer to numbers above.

1) through 4) A preweighed sterile screw-cap Erlenmeyer was used as the weighing dish; 100 ml of sterile distilled water was delivered directly onto the weighed medium. Weighing was done to 3 significant figures, i.e. 3.70 grams.

6) through 8) A preweighed sterile glass-stoppered container was used as a weighing dish. Even when stored in the dark at 2°C to 10°C this solution turned brown in 24 to 72 hours. To save chemicals, 10.00 ml was prepared when needed by weighing out 0.10 g of rosolic acid on the analytical balance.

15) Since dissolved solutes raise the boiling point of water there is no way of bringing this solution to a boil in a water bath. A water bath was used to heat the broth to 100°C and then the Erlenmeyer flask was placed directly on the hot plate, swirled periodically and removed at the first sign of boiling. The broth was then promptly cooled below 45°C by immersion in a cold water bath.

KF Streptococcus Agar was used as a growth medium for fecal streptococcus. Milipore's (3) directions are as follows:

1) Using a spatula or scoop, weigh out 7.64 grams of dehydrate into a weighing dish placed upon the laboratory balance.
2) Pour out 100 ml (0.1 liter) of distilled water into a clean 100 ml graduated cylinder.
3) Pour out approximately 20 ml of distilled water from the

graduated cylinder into a clean 250 ml screw-cap Erlenmeyer flask without spilling.

4) Empty the contents of the weighing dish carefully into the prepared 250 ml Erlenmeyer flask and swirl to disperse the dehydrate.
5) Pour the remaining contents of the graduated cylinder into the 250 ml Erlenmeyer flask without spilling.
6) Place the flask, loosely covered, in a boiling water bath.
7) Heat until the dehydrate appears completely dissolved; then heat 5 minutes more. Do not boil this medium.
8) Remove and cool to 50-60°C.
9) Add 1 ml of pure aqueous 1% solution of 2,3,5-triphenyltetrozolium chloride (TTC).
10) Adjust the pH to 7.2 with 10% sodium bicarbonate (Na_2CO_3) if necessary.
11) Liquid agar may be held in a water bath up to 4 hours at 45-50°C before pouring plates.
12) Poured plates may be store in the dark at 2-10°C for up to two weeks.

A few slight modifications of Millipore's directions were employed. Refer to numbers above:

1) through 5) A preweighed sterile 250 ml beaker was used as a weighing dish. The solution was made, heated and poured directly from this beaker.

7) Failure to heat the agar 5 minutes past the time it has reached the water bath temperature (∿100°C) may result in agar that will not harden. Note that because of the effect of dissolved solutes on boiling points, the agar will not boil in a water bath.

8) We used a sterile thermometer and a cold water bath to bring the agar down to 60°C and then placed the agar in a 60°C water bath to keep it from setting up before pouring.

9) 2,3,5-triphenyltetrozolium chloride (TTC) should be stored in the dark at 2-10°C with an expected shelf life of 2 weeks. To save chemicals 10.00 ml at a time can be prepared by weighing out 0.10 g on the analytical balance.

10) It was not found to be necessary to use Na_2CO_3 to adjust the pH.

When collecting water samples for bacteriological studies Standard Methods (4) recommends 1 hour at ambient temperature or 6 hours on ice as the maximum transport times. In order to circumvent the elapsed time problem between collection and examination, on site filtration and holding media were employed. For fecal coliform holding media Millipore's (5) directions are as follows:

> VFC Holding Medium
> This is a new (1972) broth medium developed at the EPA's Water Supply Research Laboratory to fill the need for an effective holding medium specifically for fecal coliforms. Although it is not as yet available commercially, it is easily prepared as follows (1-liter batch):
>
Vitamin-free casitone (VFC) (Difco or BBL)	0.2g
Sodium Benzoate	4.0g.
Sulfanilamide	0.5g
Ethanol (95%)	10.0ml
Distilled water	1.0liter

> In a 1-liter Erlenmeyer flask, suspend the dry ingredients in 200 ml of distilled water and add 10 ml of 95% ethanol. Place the flask, loosely covered, in a boiling water bath and heat the broth lightly to completely dissolve the ingredients. Do not over-heat (ethanol evaporates very quickly). Sterilize this medium, as needed, by membrane filtration. Use a 47mm Millipore Type GS filter (pore size = 0.22 μ) in a sterilized Sterifil Holder (see page 10). The receiver flask must be sterilized also. The Sterifil

System can accomodate up to 250 ml of sterile filtrate. Sterilize the filtration system as a unit with the filter in place. To order Type GS filters, use Millipore Catalog Number GSWP 047 00 (one hundred sterilizing grade filters in 10 resealable packets).

When kept in the dark at 2^{o}-10^{o}C this medium should have a shelf life of approximately one month. VFC was obtained through Fisher Scientific Co. under the brand name Acidase No. 2. Because of lack of equipment we used 0.45 mμ pore size filters in a stainless steel filter apparatus to sterilize the media. We used sterilized distilled water and mixed the media in sterile glassware.

KF agar plates were used as holding media for fecal streptococcus samples. Millipore's (6) directions are as follows:

Delayed Incubation

- media: M-Enterococcus Agar or KF Streptococcus Agar.
- incubation: delayed at ambient temperature, transferred to fresh agar plate upon arrival at the laboratory for incubation at 35^{o}C ±0.5^{o}C for 48 hours. See Delayed Incubation, Total Coliform for shipping procedure.
- procedure: Agar plates are poured and allowed to gel, Place prepared plates in a chilling apparatus (dry ice and container, etc.) for field storage. Perform filtration of sample in the field according to Section VI. Place the MF on the agar plate and seal tightly. Transfer the preserved culture to the laboratory in a suitable container (depending on mode of transportation). Upon arrival at the laboratory, transfer the MF culture from the preservative agar plate to a fresh agar plate. Invert cultures prior to incubation.

Some problems occurred with the agar softening and with condensation in the Petri dishes, resulting in smeared plates and strep growing on the bottom of the filter. The bacteria were washed down, we hypothesize, with the condensation and movement in the backpack. Plates

should be carried to the trail heads in an ice chest and kept in an upright position in a backpack until transfer to a fresh plate in the lab for incubation. Endothermic chemical reaction ice packs carried on the trail might be a solution (an expensive one) to this problem.

Equipment

125 ml Nalgene grab sample bottles, screw top glass Erlenmeyer flasks and distilled water in 4 liter Nalgene bottles were sterilized in an autoclave at 15 p.s.i. (250°F) for 15 minutes. Making certain that the tops on all bottles in the autoclave were loose prevented crushing of plastic bottles from pressure changes.

Pipettes in a steel container were sterilized by heating in a dry oven at 178°C for two hours. Various other pieces of glass and steel lab apparatus were periodically sterilized by dipping in isopropyl alcohol, flaming, and drying at 110°.

For filtering in the field the equipment used was:

1. Sterifil Aseptic System, 47 mm
2. Sterifil Holder, 47 mm
3. Hand Vacuum Assembly
4. Stainless Steel Forceps
5. 400 ml Nalgene beaker
6. Type HA filters
7. VFC and KF agar holding plates

8. One pint of isopropyl alcohol

9. Butane lighter

The Sterifil funnel was sterilized in the field by submerging it in the 400 ml beaker full of isopropyl alcohol for 1 minute. The alcohol was then returned to its plastic bottle for reuse later. The excess alcohol was then thoroughly rinsed from the beaker and funnel with the water to be sampled. The forceps were sterilized between each handling of the filter by dipping in isopropyl alcohol, flaming with the butane lighter and cooling. Matches tend to leave soot on the forceps that then gets on the filter.

RESULTS

The results of this study are summarized below in a series of frequency tables. These show the number of samples for which fecal coliform counts fell within the range indicated. Full tables of all test results are presented in an appendix. Figures are for the fecal coliform group and represent bacteria per 100 ml. Maintained drinking water sources may have a coliform count of no more than one per 100 ml as the arithmetic mean of all samples examined (7). Water containing fecal counts of over 200 per 100 ml is considered unsafe for swimming (8). The coliform counts from the streams in Cades Cove are much higher than those from other parts of the park, and therefore, have been tabulated separately.

Table I. Summary of Backcountry Water Samples

(All samples except Cades Cove)

	Range of Fecal Coliform Counts					
Bacteria/100 ml	0	1-10	11-30	31-100	>100	Total
Number of samples	50	102	18	7	2	179
Percent	28%	57%	10%	4%	1%	100%

Data from different types of water sources is compared in Table II. Sources are defined as follows: A primary stream is a stream fed mainly by a spring or by seepage. A secondary stream is a stream fed by various tributaries. A flowing spring is a spring which flows from localized source and can be sampled directly as it comes from the ground. A seepage spring is a spring which seeps from the ground over a wide area and from which water can be obtained in quantities sufficient for sampling or drinking only after it has flowed over the surface of the ground for a considerable distance.

Table II. Comparison of Different Types of Back-country Water Source (not including Cades Cove samples).

Source Type	Range of Fecal Coliform Counts					No. Samples
	0	1-10	11-30	31-100	>100	
Primary Stream	7 32%	4 20%	4 20%	5 24%	1 4%	21
Secondary Stream	11 15%	55 77%	5 7%	1 1%	0 0%	72
Flowing Spring	23 72%	9 28%	0 0%	0 0%	0 0%	32
Seepage Spring	7 33%	8 40%	3 15%	2 8%	1 4%	21
All Streams	18 20%	59 62%	9 10%	6 7%	1 1%	93
All Springs	30 57%	17 32%	3 5%	2 4%	1 2%	53

Table III. Average and Maximum Fecal Coliform Counts for Different Types of Back-country Water Source.

Type of Source	Average	Maximum
Primary Stream	12	50
Secondary Stream	4.3	32
Flowing Spring	0.4	3
Seepage Spring	17	173

Data was also collected from above and below campsites and outhouses to determine the effects of these types of facilities.

Table IV. Fecal Coliform Counts from Above and Below Campsites.

Campsite No.	8	8	9	24	24	50	55	12	12	12
Count above Campsite	8	4	4	4	4	0	14	25	3	5
Count below Campsite	12	6	10	2	2	1	9	15	2	6

Table V. Coliform Counts from Outhouse Drainages.

As no data were collected from above outhouses these can only be compared to similar situations where no outhouses were present.

Average spring drainage without outhouse	(n=3)	70 per 100 ml.
Average spring drainage with outhouse	(n=4)	35 per 100 ml.

Sample size was too small to draw any conclusions, but the outhouses do not seem to have a major effect on the bacteriological quality of the water in the areas tested.

In Cades Cove, large amounts of contamination from livestock were found in the streams. Table VI. presents fecal coliform counts

from the streams of Cades Cove above and below their first contact with cattle or horse pastures.

Table VI. Fecal Coliform Counts in Cades Cove. Percentages of samples within ranges.

	0-20	20-200	200-1000	>1000	Total
Streams above first contact with livestock	7 35%	12 60%	1 5%	0 0%	20 100%
Streams below first contact with livestock	0 0%	8 12%	30 47%	26 41%	64 100%

An effort was made to determine if the source of contamination was human or animal by use of the ratio of fecal coliform to fecal streptococcus. Table VII represents the fecal coliform to fecal streptococcus ratios for samples from Cades Cove and then from backcountry areas in the park. Only samples where the fecal streptococcus count was at least 100 have been included, as Geldreich (9) indicates that values below 100 may not be significant. Ratios less than or equal to 0.7 usually indicate pollution derived from livestock, wildlife or poultry. Ratios greater than or equal to 4 indicate pollution derived from human wastes. Ratios from .7 to 1.0 suggest a predominance of non-human animal waste and a ratio between 2 and 4 a predominance of human waste. Ratios between 1 and 2 are

usually of "uncertain interpretation" (10).

The ratios included in the Cades Cove data are all from areas downstream from cow and horse pastures. The wildlife densities in this area are also very high compared to many of the forested areas in the park. Most of the ratios from Cades Cove fall in the animal range (80%) and none are clearly human. For the remainder of the park, 90% of the ratios are in the animal range and 4 (10%) indicate a predominance of human pollution. These samples are from the spring at Russell Field Shelter and lower Cooper Creek. In the latter case, the pollution was almost certainly human, and in the former it may well have been.

Table VII. Fecal Coliform/Fecal Streptococcus for Samples from Cades Cove and All Other Areas Tested (Fecal streptococcus counts greater than 100).

	Ranges of ratios					
	0-.7	.7-1.	1-2	2-4	>4	Total
Cades Cove						
Number of samples	51	5	7	7	0	70
Percentage	73%	7%	10%	10%	0%	100%
All other areas						
Number of samples	27	11	0	0	4	42
Percentage	64%	26%	0%	0%	10%	100%

DISCUSSION

Sampling Methods

The Millipore Membrane Filtration method seems to be quite suitable for backcountry water sampling. The plastic apparatus used is both lightweight and convenient. The holding media was effective in preserving samples for up to 72 hours from the time of sampling. In heavily contaminated water, however, there was no way of measuring small enough samples without carrying pipettes or a graduated cylinder. Water which was inaccessible enough to require filtering in the field was generally clean enough so that dilution was no problem.

Sources of Contamination

The general indication was that contamination came most often from animal rather than human sources. Although, in a few places, there were obvious sources such as the cattle in Cades Cove, in most areas this was not the case. Future studies, by analyzing different strains of streptococcus, might determine which species (i.e., hogs, bears, deer, etc.) are responsible for contamination. Even though only one backcountry source at a campsite provided a human ratio for fecal coliform to fecal streptococcus, it should be remembered that animals can, in some cases, carry pathogens which also affect humans. It should also be noted that the organisms are subject to differential die-off rates and the ratios may not be accurate, at a distance from

the source of contamination (Die-off is usually significant 24 hours flow away from the source).

Animals may act as vectors of human disease when they take water from streams contaminated with human waste or otherwise ingest waste from infective humans. This may be important with the free ranging wild hog populations rooting around the backcountry camp-sites (cat holes) and later contaminating water sources.

Patterns of Fecal Contamination

Most contamination entering streams comes from surface runoff. Water flowing in small quantities over soil tends to give high coliform counts, as it has the chance to come in contact with contamination. This is supported by data from the drainage below springs, very small streams, and one stormwater runoff sample from Mt. LeConte. Samples taken from five to ten meters below springs sometimes gave plates with too many colonies to count. Admittedly these springs were in areas heavily used by both humans and wildlife. The low counts given at the sources of the same springs emphasize the contrast between ground water and surface water.

The outhouses (pit toilets) at Spence Field and Moore Spring Shelter, presented a concentrated source of contamination close to, and uphill from a quite small stream. There was, however, little evidence that large amounts of contamination were reaching the streams from the outhouses. The counts from the drainages below these springs were actually somewhat lower than those from similar springs where the outhouses were far from the water. This was not a significant difference, but it seemed to indicate that very little contamination is being transmitted in the groundwater.

This rapid contamination of springwater after it leaves the ground is important in interpreting data from different springs. Some springs flow out of a very localized source and can be collected

for sampling or drinking immediately as the water leaves the ground. Other springs seep from the ground over a fairly wide area and the water must flow across the surface before it can be collected for sampling or drinking. Springs of the first type never gave a coliform count higher than 4. Springs of the second type frequently gave counts greater than 20. This was taken as an indication that surface runoff is a major source of backcountry water contamination.

In the backcountry, primary streams fed by springs and seepage, gave average coliform counts of over 10 and frequently gave counts over 30. Secondary and higher order streams, fed by tributaries, gave average counts of under 5. With the exception of the Abrams Creek watershed, no counts over 32 were obtained from a secondary stream, and none over 10 except during periods of heavy rainfall.

Another major difference between different types of water source was in the variability of the coliform counts. Secondary streams tended to be quite consistent in their counts, with 77% of the counts from these streams falling between 1 and 10. Primary streams and springs were much more variable, giving both more counts of 0 and more counts greater than 10, than larger streams did. Even for a series of samples from the same source, there was considerable variation with springs and primary streams. All primary streams sampled, which gave a count of over 10, at other samplings gave counts of 0 or 1 (with one exception). Most high counts from springs came

from sources which also gave a count of 0 on another sampling date. No secondary stream giving a count higher than 10 gave another count below 5, although most large streams giving higher counts were sampled only once.

The reason for this difference in variability is that secondary streams are fed by water from a much greater area and hence a much wider variety of sources. Wide fluctuations in one or more tributaries will be minimized by the great volume of water from other sources. In order to produce a significant change in a secondary stream, there must be a synchronized change in the amount of contamination coming from a large number of its tributaries. Most significant increases in coliform counted on secondary streams corresponded with periods of rainfall which affected the entire watershed. Springs and primary streams, on the other hand, were subjected to much more localized and undiluted sources of contamination. Large fluctuations in the coliform concentrations could result from use of the water by only a few animals. High counts at these water sources were not necessarily associated with heavy rainfall.

In general, it seemed that fecal coliform counts are both lower and more consistent in secondary streams. Springs where the water can be obtained directly as it comes out of the ground also seemed to give consistently low counts. Primary streams and springs where water cannot be obtained directly as it comes from the ground tended

to give both higher and more variable counts than other types of water source.

Problem Areas

The most severe water quality problem in the areas of the park tested was unquestionably in the Abrams Creek watershed. The cattle and horses which grazed in Cades Cove produce coliform counts of over 10,000 per 100 ml. in some of the small streams in Cades Cove and over 1000 in parts of Abrams Creeks. The cource of this contamination was primarily the cattle. Measurements along streams which pass through pastures show an almost perfect correlation between increased coliform counts and the presence of cows (see maps and tables in appendix). Coliform counts increased as a stream flowed through a pasture and decreased after it left the pasture.

The Tennessee water quality standards for recreational waters state:

> "the concentration of the fecal coliform group shall not exceed 200 per 100 ml. as the logarithmic mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours"(11).

Samples taken from Abrams Creek at Hyatt Lane and above Mill Creek gave logarithmic means of 1550 per 100 ml. and 610 per 100 ml. respectively. Abrams Creek at Sparks Lane was very close to the limit with a logarithmic mean of 176 per 100 ml. In addition, the

water quality criteria state that "the concentration of the fecal coliform group in any individual sample shall not exceed 1000 per 100 ml. (12)." Concentrations of coliform higher than 1000 per 100 ml. have been found in all sampling sites on Abrams Creek from Cooper Branch, just below Sparks Lane, down to the lower end of Cades Cove. After heavy rain a count of over 2000 was obtained just above Abrams Creek Campground, more than seven miles downstream from the suspected source of contamination.

Another possible problem area is the springs at the shelters along the Appalachian Trail. Although most of these springs were almost free of contamination, a few, notably Russell Field, Birch Spring Gap, and Tricorner Knob, consistently produced significant coliform counts. A count of 173 per 100 ml. came from Tricorner Knob. Counts of over 25 came from both springs at Double Springs Gap and the upper spring at Russell Field Shelter. The counts from many of these springs were quite variable. Some springs appeared free of contamination in one sample and then gave counts of 25 or 30 in the next. One is led to suspect even those springs which have showed no contamination the few times they have been tested may occasionally produce positive counts.

One trend was apparent. Some springs flowed in substantial volume out of a very localized source and water can be obtained in quantities sufficient for drinking or sampling immediately after the water came from the ground. The water had no chance to pick up

contamination from the surface before it was sampled. At other springs the water seeped from the ground over an area several meters square and traveled along the surface for some distance before collecting in sufficient quantity to be sampled. This water therefore had the opportunity to accumulate considerable amounts of contamination from the surface before it was collected for sampling or drinking. It was from this second type of spring that many of the high counts were obtained. The second type of spring also produced much more variable coliform counts than a flowing spring of the first type. No counts of over 4 came from a spring sampled as the water came from the ground. Counts ranging from 0 to 173 have come from springs sampled after as little as 5 m of flow on the surface. Counts from a single sampling site at such a spring have ranged from 0 to 70. A majority of the samples from springs on the Appalachian Trail had very little contamination, but any of them could probably produce a high count if tested when a source of contamination was present nearby. The quality of water from these springs is unpredictable.

Except for small streams running over soil and vegetation, stream water in general showed very little contamination. The highest coliform count obtained from a major stream outside of the Cades Cove area was 32. Only 7 counts over 10 were obtained from major streams. Most of these were during or after periods of rain, when there was much surface runoff present in the streams. In most

ACKNOWLEDGEMENTS

The field work for this project was supported by funds provided by the Great Smoky Mountains Natural History Association. We gratefully acknowledge their financial support of this research.

We would like to thank all volunteers and park staff who helped collect water samples. Rosemary Nichols provided some of the samples and data from the Mt. LeConte section.

We would like to thank Wayne Williams, the Park Sanitarian, for advice, assistance in the lab, and help in preparation of this manuscript. Marti Peterson and Dr. Ray Herrmann provided logistic support for the project. Dr. Susan Bratton edited the final copy and provided advice and logistic support throughout.

REFERENCES

1. Biological Analysis of Water and Wastewater, Application Manual AM302, Millipore Corp., 1973.

2. Ibid, pp. 21-22.

3. Ibid, pp. 22-23.

4. Standard Methods for the Examination of Water and Wastewater 13th Ed., American Public Health Assoc. publication, 1971, p. 659.

5. Biological Analysis of Water and Wastewater, Applications Manual AM302, Millipore Corp., 1973, p. 22.

6. Ibid, p. 38.

7. Standard Methods for the Examination of Water and Wastewater, 13th Ed. American Public Health Assoc. publication, 1971.

8. Design Criteria Including Laws, Regulations and Policies for Water and Wastewater Systems, Tennessee Department of Public Health publication, 1972, p.7.

9. Geldreich, Edwin E. Applying Bacteriological Parameters to Recreational Water Quality. J. Am. Water Works Assoc. 1970. 62:113-120.

10. Directions for Fecal Coliform/Fecal Strep Ratio. Millipore Corp.

11. Design Criteria Including Laws, Regulations and Policies for Water and Wastewater Systems, Tennessee Department of Public Health Publication, 1972. p.7.

12. Ibid, p. 7.

APPENDIX

All data used in this report is presented here. Data is organized in sections, starting with Cades Cove and proceeding clockwise around the park. Sites along the Appalachian Trail are placed separately at the end. Sites are numbered and displayed on maps included with each section. Source type refers to the type of source from which the sample was taken. This is only included for backcountry sampling.

1 indicates a large tributary-fed stream

2 indicates a small stream fed by seepage or a spring.

3 indicates a flowing spring.

4 indicates a seepage spring.

* next to the date sampled indicates that the sample was taken during or immediately after a period of heavy rainfall.

THTC too high to count

Two sets of figures in a column indicates duplicates were run. These figures were averaged and treated as a single value.

CADES COVE

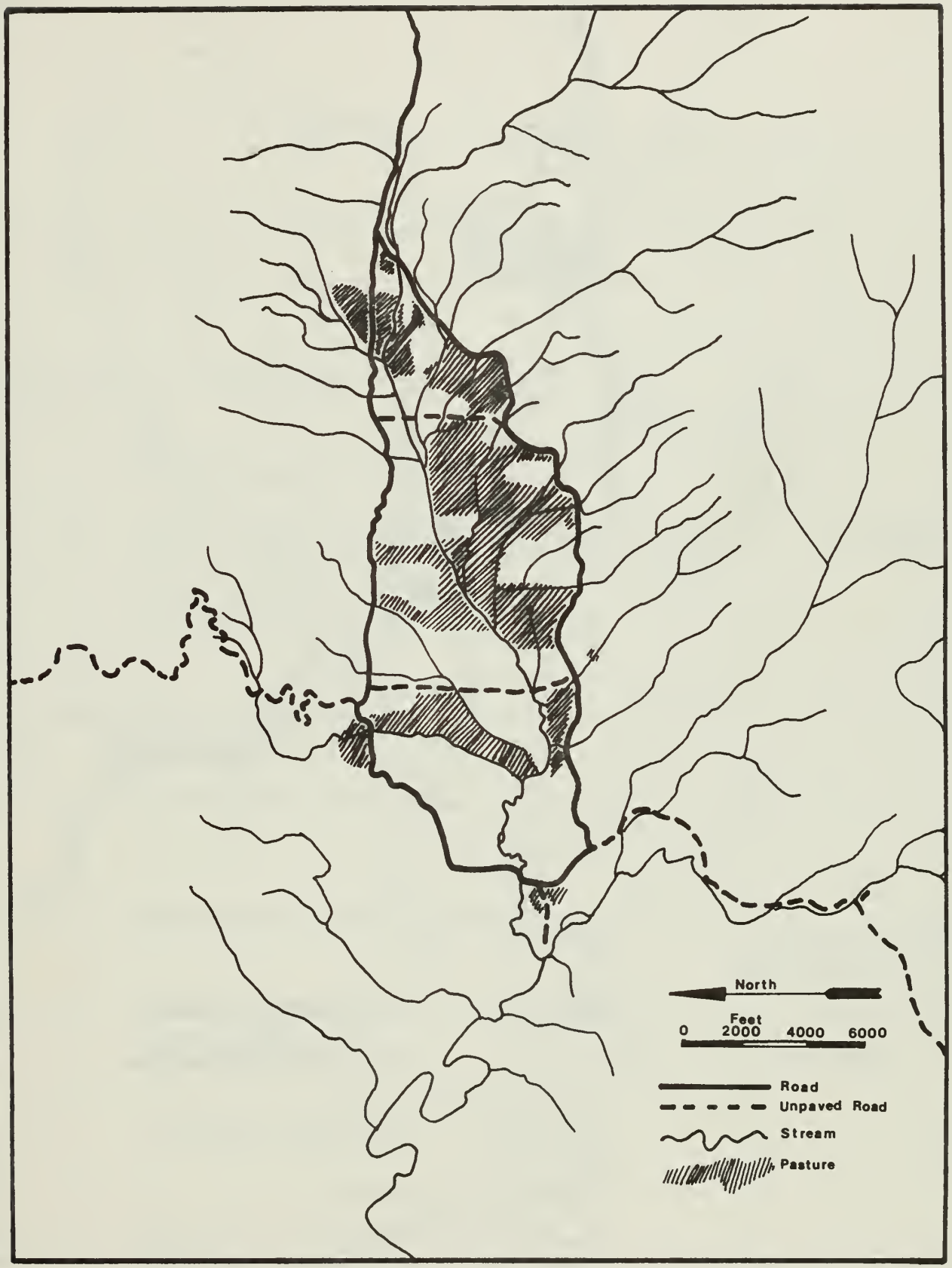
This section includes data from Abrams Creek and its tributaries in Cades Cove and downstream. Contamination is primarily from livestock pastured in Cades Cove. A map indicating the location of cattle at the time of sampling is included.

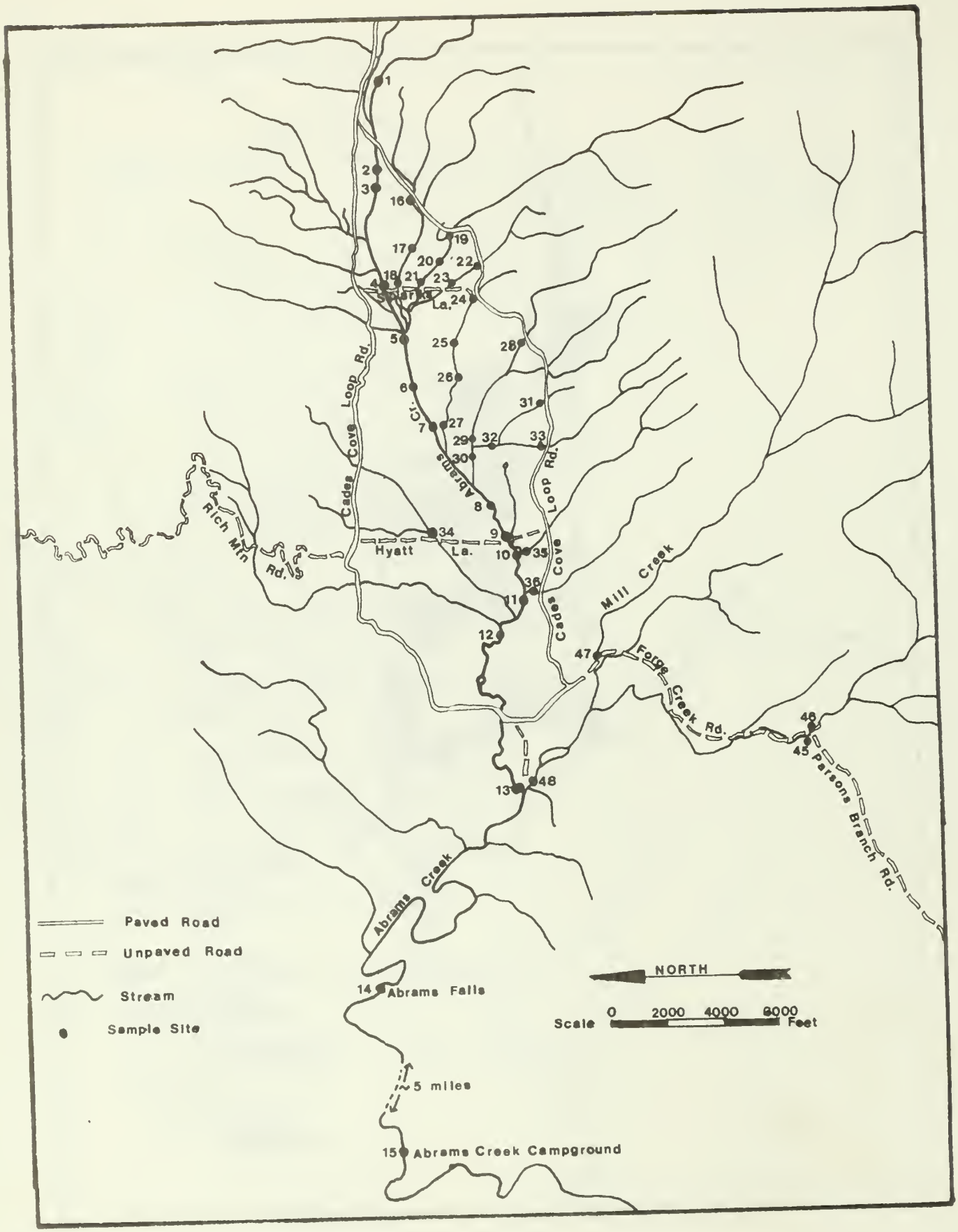
Sample No.	Location of Sample	Date	Fecal Coliform per 100 ml	Fecal Streptococcus per 100 ml
1	Abrams Creek at Cades Cove Picnic Area	6/2	6	79
		7/13	0	1000
		7/15	10	940
		7/16	10	880
		7/18	40	730
		7/22	30	970
		7/24	THTC(∿500)	-
		7/28	60	-
		8/4	12	-
2	Abrams Creek above Sewage Lagoon	6/2	20	150
		7/22	150	2080
3	Abrams Creek below Sewage Lagoon	6/2	18	91
4	Abrams Creek at Sparks Lane	6/27*	440 410	690 850
		7/1	50	1150
		7/9	200	570
		7/12	100	1950
		7/13	150	1950
		7/15	80	1890
		7/16	270	4480
		7/18	80	2610
		7/21	40	2010
		7/22	120	1970
		7/24	330	-
		7/28	400	-
		log. mean	176	-

Sample No.	Location of Sample	Date	Fecal Coliform per 100 ml	Fecal Streptococcus per 100 ml
5	Abrams Creek below Intersection with Cooper Branch	7/1	350	1550
		7/24	1040	-
6	Abrams Creek at Fenceline	7/24	1850	-
7	Abrams Creek near Primitive Baptist Church	7/24	4350	-
8	Abrams Creek below Pastures above Hyatt Lane	7/1	750	1750
		7/24	215	-
9	Abrams Cr. at Hyatt Lane	6/27*	4260 5320	1250 1820
		7/9	670	940
		7/12	2170	1650
		7/13	840	1570
		7/15	1650	4110
		7/18	1290	940
		7/21	4960	1980
		7/22	1650	740
		7/24	18300	-
		7/28	4080	-
		7/30	9700	-
		log. mean	1550	-
10	Abrams Creek below Cades Branch	7/1	1500	1550
		7/28	3100	-
11	Abrams Creek below Whistling Branch	7/28	3640	-
12	Abrams Creek below Tater Branch	7/28	2120	-
13	Abrams Creek above Intersection with Mill Creek	6/2	453	400
		6/8	488	295
		6/23	460 420	170 180
		6/27*	1620	1350
		7/1	200	950
		7/9	850	1170
		7/13	440	1150
		7/15	890	1520
		7/18	240	670

Sample No.	Location of Sample	Date	Fecal Coliform per 100 ml	Fecal Streptococcus per 100 ml
13	Abrams Creek above Intersection with Mill Creek	7/21	1440	2280
		7/22	790	1500
		7/24	1650	-
		7/28	380	-
		log. mean	610	-
14	Abrams Creek at Abrams Falls	6/7	65	150
		7/13	20	660
		7/21	50	870
		7/22	60	520
		7/28	80	-
		log. mean	52	-
15	Abrams Creek at Abrams Creek Campground	6/29*	2040 2070	THTC 2380
		7/21	30 40	3160 2110
		7/23	13	216
		7/25	11	THTC
		7/28	25	-
16	Cooper Branch at Loop Road	7/1	50	105
		7/9	70	300
		7/22	0	1690
17	Cooper Branch at Barn	7/1	700	1300
		7/9	500	910
		7/22	5420	2090
18	Cooper Branch at Sparks Lane	7/1	750	1500
		7/9	840	630
		7/22	1450	2840
19	Rowans Creek at Loop Rd.	7/22	0	4380
20	Rowans Cr. at Fence Line	7/22	1020	3250
21	Rowans Cr. at Sparks Lane	6/27*	390 240	810 910
		7/22	120	3100
22	Sea Branch at Loop Road	7/22	20	1040

Sample No.	Location of Sample	Date	Fecal Coliform per 100 ml	Fecal Streptococcus per 100 ml
23	Sea Branch at Sparks Lane	6/27*	2330 2190	1560 2570
		7/22	220	6000
24	Maple Br. at Loop Road	7/24	34	-
25	Maple Branch at Fence in Pasture	7/24	39 600	-
26	Maple Branch below Pasture	7/24	1100	-
27	Maple Branch at Primitive Baptist Church	7/24	4260	-
28	McCaulley Branch at Loop Road	7/24	24	-
29	McCaulley Branch above Oliver Branch	7/24	380	-
30	McCaulley Branch below Oliver Branch	7/24	950	-
31	Oliver Branch at Loop Rd.	7/24	100	-
32	Oliver Branch below Fork	7/24	860	-
33	West Fork of Oliver Branch at Loop Road	7/24	4	-
34	Feezell Branch at Hyatt Lane	6/27*	1630	-
35	Cades Branch above Abrams Creek	7/28	380	-
36	Whistling Branch above Abrams Creek	7/28	460	-


North
Feet
0 2000 4000 6000
Road
Unpaved Road
Stream
Pasture


Paved Road
Unpaved Road
Stream
Sample Site
NORTH
Scale 0 2000 4000 6000 Feet
~5 miles
Cades Cove Loop Rd.
Abrams Cr.
Rich Mtn Rd.
Hyatt La.
Mill Creek
Forge Creek Rd.
Parsons Branch Rd.
Abrams Creek
14 Abrams Falls
15 Abrams Creek Campground

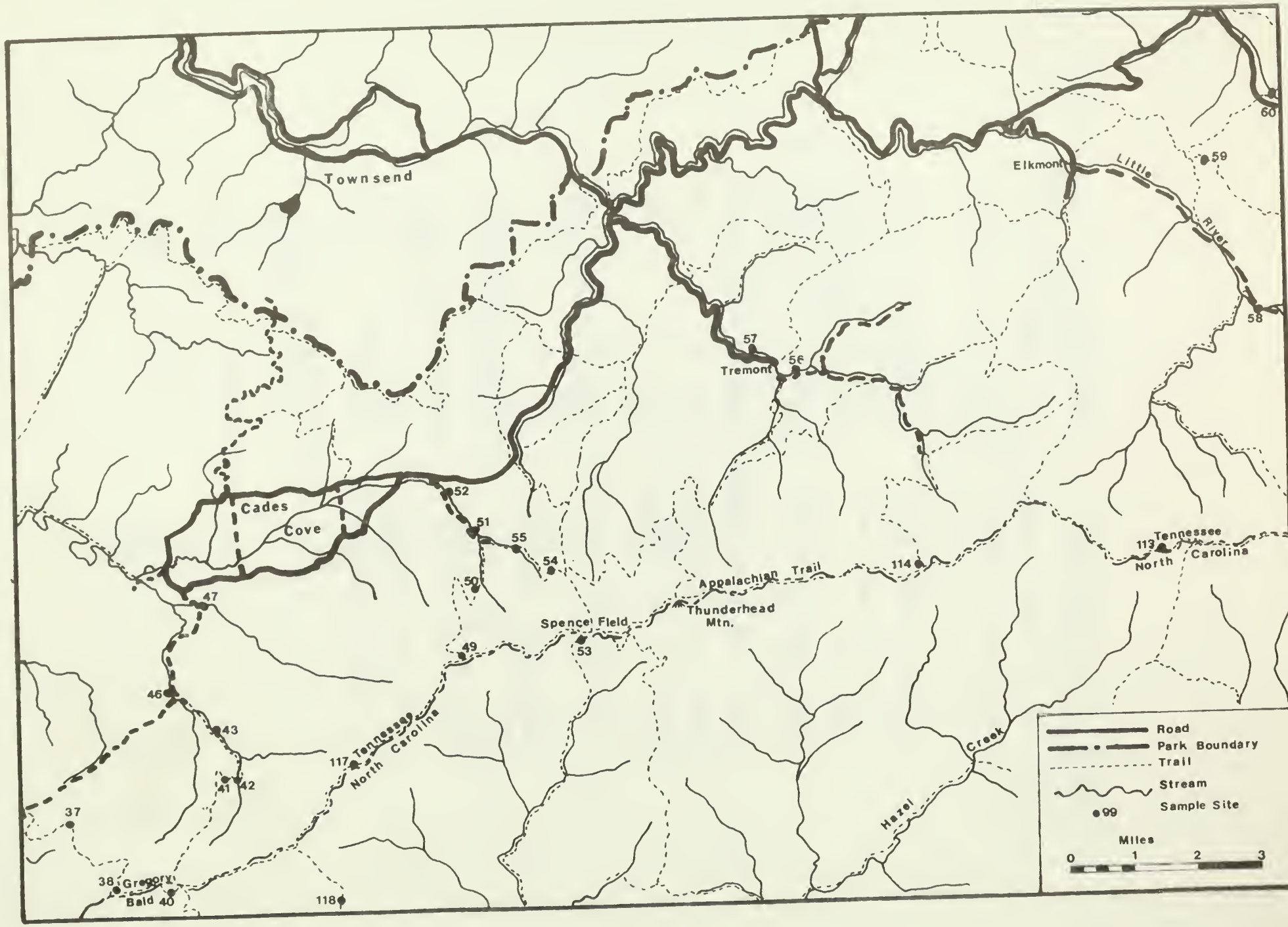
CADES COVE TO SUGARLANDS

This section includes all backcountry sampling from the ridges to the south of Cades Cove east to the Newfound Gap Road.

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.	Fecal Strep per 100 ml.
37	2	Hannah Mountain Trail	6/11*	0	60
38	4	Sheep Pen Gap - Upper Source	6/11*	2	80
			7/29	16	-
	3	Sheep Pen Gap - Lower Source	6/11*	0	140
			7/3	0	-
			7/29	2	-
			8/12	0	-
	2	Sheep Pen Gap 10 meters below Lower Source	8/12	50	-
40	3	Moore Spring at Source	6/11*	0	106
			7/3	0	-
			7/29	0	-
			8/12	1	-
	2	Moore Spring below Outhouse	6/11*	0	80
			7/29	15	-
			8/12	57	-
41	2	First Small Stream down Gregory Ridge Trail	7/3	1	-
			7/29	1	-
			8/12	24	-
42	1	Forge Creek at Highest Bridge on Gregory Ridge Trail	6/11*	2	90
			7/3	6	-
			7/29	4	-
			8/12	6	-
43	1	Forge Creek above Campsite #12	6/11*	25	72
			7/3	3	-
			8/12	5	-

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
	1	Forge Creek below Campsite #12	6/11*	15		126	
			7/3	2		-	
			8/12	6		-	
45	3	Spring at beginning of Parson's Branch Road	6/2	0		1	
			6/8	1		133	
46	1	Forge Creek at Parson's Branch Road	6/8	15		95	
47	1	Mill Creek at First Bridge	6/8	25		337	
48	1	Mill Creek above Abrams Creek	6/2	107		133	
			6/8	48		140	
			6/23	60		280	
			6/27*	60		1500	
			7/9	30		590	
			7/13	60		1250	
49	4	Russel Field Shelter - Upper Source	6/27*	39	62	1	0
			6/28*	6	4	3	2
			8/4	1		-	
	2	Russell Field Shelter 10 meters below Upper Source	6/27*	THTC		129	177
	3	Russell Field Shelter - Lower Source	7/11	1	3	10	6
			8/4	1		-	
50	1	Stream at Campsite #10	6/27*	4	4	116	175
			8/4	10		-	
51	1	Anthony Cr. below Junction of Spence and Russell Field Trails	6/27*	2	3	120	215
			8/4	2		-	
52	1	Anthony Creek above Campsite #8	6/27	4	4	116	175
			8/4	8		-	
53	4	Spence Field Shelter at Source	6/27*	2	4	7	8
			6/28*	0	0	183	33
			7/11	1	0	13	33
			8/4	2		-	

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
53	2	Spence Field Shelter below Outhouse	6/27	37	29	46	47
54	2	Spence Field Trail at Stream near Bote Mountain Road	6/27* 8/4	11 14	14	55 -	143
55	1	Spence Field trail above Campsite #9	6/27* 8/4	2 3	6	84 -	65
	1	Spence Field Trail below Campsite #9	6/27* 8/4	11 3	10	43 -	56
56	1	Middle Prong above Tremont	7/13	4		262	
57	1	Middle Prong below Tremont	7/13	4		292	
58	1	Rough Creek above Campsite #24	7/23 7/31	4 4		214 -	
	1	Rough Creek below Campsite #24	7/23 7/31	2 2		148 -	
59		Campsite #21, Sugarlands Mountain Trail	6/10	0		37	
	3	Spring below Sugarlands Mountain Trail	6/10	1		1	
60	1	Main Stream at Campsite #22	6/10	7		120	
	2	Side Branch at Campsite #22	6/10	8		155	


Townsend
Elkmont
Little River
Tremont
Cades Cove
Appalachian Trail
Thunderhead Mtn.
Spence Field
Tennessee
North Carolina
Hazel Creek
Gregory Bald
Road
Park Boundary
Trail
Stream
Sample Site
Miles
0 1 2 3

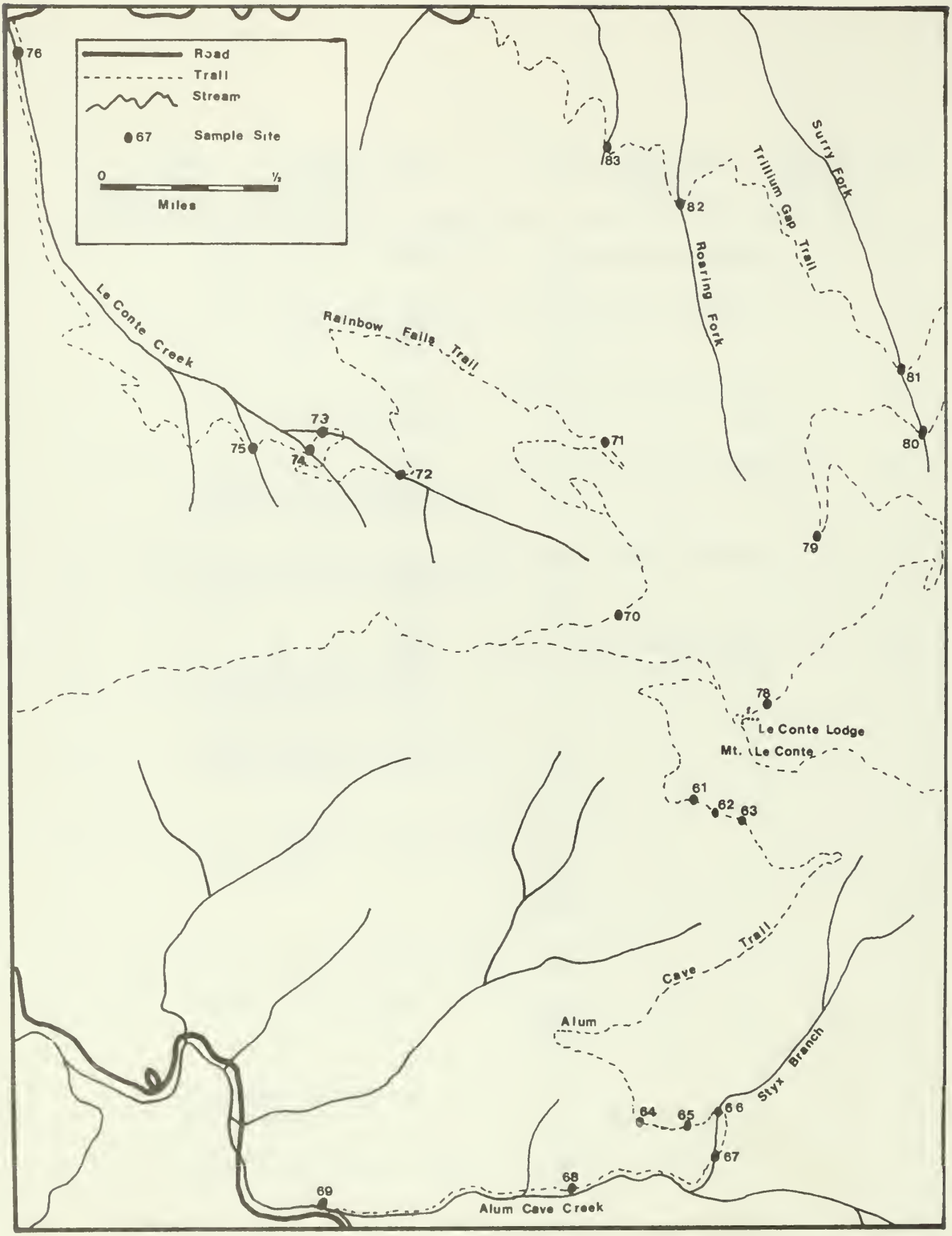
MT. LECONTE

This section includes data from three trails on the north and west slopes of Mt. LeConte. The Alum Cave Trail, Rainbow Falls Trail, and Trillium Gap Trail were sampled in conjunction with a study on the impact of LeConte Lodge on the surrounding area done by Rosemary Nichols. These streams may contain drainage from the lodge area.

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
61	2	First Freshet down Alum Cave Trail	7/5	0	0	1	22
			7/27	0	0	0	0
			8/10	6	12	-	
62	4	Seepage Slope on Alum Cave Trail	7/5	0	0	0	2
63	2	Second Freshet down Alum Cave Trail	7/5	0	0	0	2
			8/10	0	0	-	
64	1	First Stream down Alum Cave Trail	7/5	1	2	1	4
			8/10	0	1	-	
65	1	Stream above Stya Branch on Alum Cave Trail	7/5	1	0	0	2
66	1	Stya Branch at first crossing down Alum Cave Trail	7/27	32	25 29	-	
67	1	Stya Branch at Arch Rock	7/27	1	2	-	
			8/10	0	1	-	
68	1	Alum Cave Creek at sign about mountain stream	7/5	2	0	6	1
			7/27	2	4	-	
			8/10	1	0	-	

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.			Fecal Strep per 100 ml.	
69	1	Walker Prong at Alum Cave Parking Area	7/5	1	1		1	3
70	2	First Stream down Rainbow Falls Trail	7/5	0	0		1	5
			7/27	0	0		0	0
			8/10	0	0		-	
71	2	Stream below Rocky Spur	7/5	1	0		4	0
			8/10	0	0		-	
72	1	LeConte Creek at first crossing dwon Rainbow Falls Trail	7/5	0	0		32	3
			8/10	0	0		-	
73	1	LeConte Creek below Rainbow Falls	6/28	0	0		83	60
			7/5	0	0		24	59
			7/27	1	2		-	
			8/10	2	3		-	
74	2	First Tributary below Rainbow Falls	7/27	0	1		-	
			8/10	1	3		-	
75	1	Second Tributary below Rainbow Falls	7/5	2	3		15	50
			7/27	0	1		-	
			8/10	0	0		-	
76	1	LeConte Creek at Bridge above Horse Trail	6/28	2	0		115	631
			7/5	3	3		26	59
			7/27	2	1		-	
			8/10	1	1		-	
77	1	LeConte Creek at Uplands Lab	6/28	5			87	
78	3	Spring on Mt. LeConte	7/5	0	1	1	6	4
			7/27	0	0		0	0
			8/10	1	0		-	
	2	Stormwater Runoff on Mt. LeConte	7/5	17	16	17	14	9
	1	Horse Trough on Mt. LeConte	8/10	0	0		-	

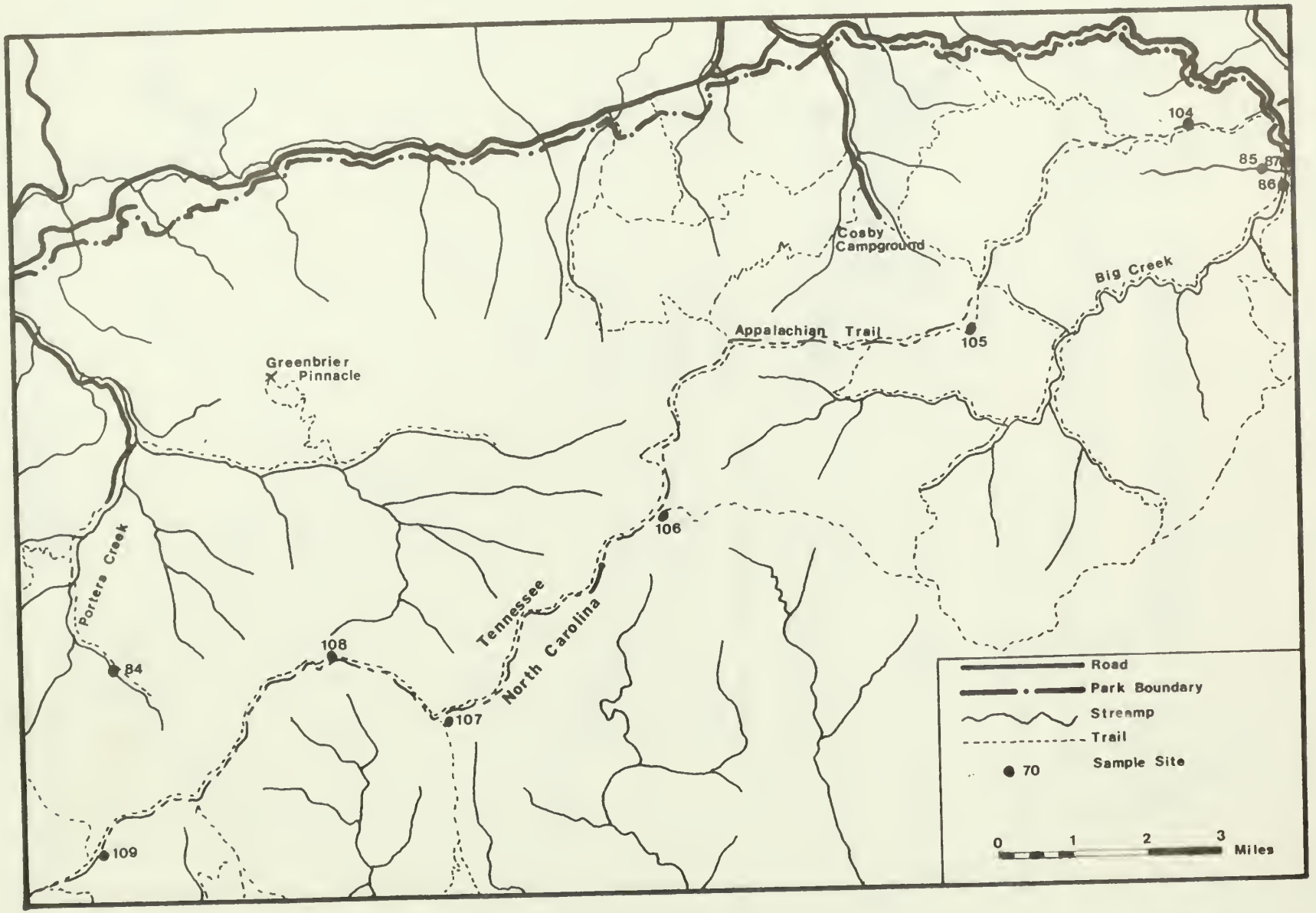
Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
78	1	Hydraulic Ram Outlet	8/10	0	1	-	
79	2	Roaring Fork at 5200 feet	7/5	0	0	21	4
			7/27	1	0	-	
			8/10	3	4	-	
80	2	Surry Fork above Trillium Gap	7/5	0	0	0	1
			8/10	0	2	-	
81	2	Surry Fork below Trillium Gap	7/5	6	8	7	34
			7/27	1	0	-	
			8/10	6	2	-	
82	1	Roaring Fork at Grotto Falls	7/5	4	4	37	31
			7/27	2	3	-	
			8/10	4	1	-	
83	1	First Stream above Road on Trillium Gap Trail	7/27	1	0	-	
			8/10	15	19	-	


Road
Trail
Stream
67 Sample Site
0
½
Miles
76
83
82
Roaring Fork
Trillium Gap Trail
Sugar Fork
81
80
79
Le Conte Creek
Rainbow Falls Trail
73
75
74
72
71
70
78
Le Conte Lodge
Mt. Le Conte
61
62
63
Cave Trail
Alum
Styx Branch
64
65
66
67
68
69
Alum Cave Creek

GREENBRIER AND BIG CREEK AREAS

This section includes just a few sample sites between Mount LeConte and the east end of the park.

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.	Fecal Strep per 100 ml.
84	1	Porters Creek below Campsite #31	6/24*	1	28
85	1	Chestnut Branch above Big Creek	6/24*	32	384
86	1	Big Creek at Campsite #32	6/26*	22	171
87	1	Big Creek at Bridge at Park Boundary	6/26*	27	138

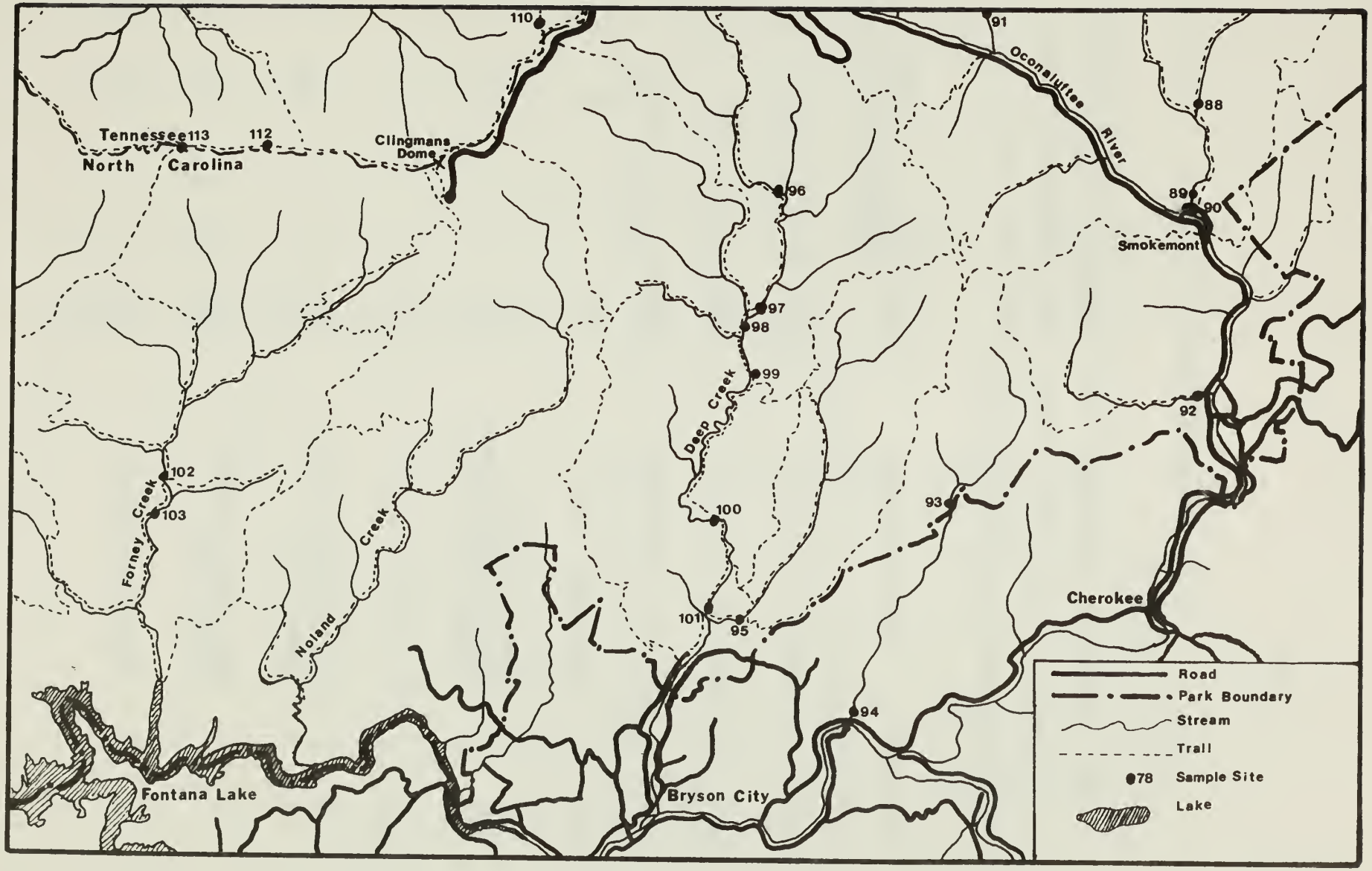

104
85
87
86
Cosby
Campground
Big Creek
Appalachian Trail
105
Greenbrier
Pinnacle
106
Porters Creek
Tennessee
North Carolina
108
84
107
109
Road
Park Boundary
Streamp
Trail
70
Sample Site
0
1
2
3
Miles

NORTH CAROLINA AREA

This section includes a few of the major streams draining the central portion of the North Carolina side of the park.

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
88	1	Chasteen Creek above Campsite #50	6/12*	0		73	
89	1	Bradley Fork above Smokemont	6/12*	2		215	
90	1	Bradley Fork below Smokemont	6/12*	4		356	
91	1	Kephart Prong above Kephart Shelter	7/8	1		35	
	1	Kephart Prong below Kephart Shelter	7/8	0		47	
92	1	Mingus Creek below Mingus Mill	6/10	0		137	
93	1	Cooper Creek at Park Boundary	6/3 6/24*	5 1	 2	82 55	 76
94	1	Cooper Creek at U.S. Route 19	6/3 6/24*	111 THTC		422 350	 350
95	1	Indian Creek below Falls	6/24* 6/30*	6 14	4	181 135	256
96	1	Deep Creek above Campsite #53	6/30*	9		110	
97	1	Nettle Creek near Campsite #54	6/30*	9		163	

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
98	1	Deep Creek above Campsite #55	6/30*	14		124	
99	1	Deep Creek below Campsite #57	6/30*	7		143	
100	1	Deep Creek at First Bridge	6/30*	16		146	
101	1	Deep Creek above Indian Creek	6/30*	9		116	
			6/24*	4	0	150	128
102	1	Forney Creek at Crossing above Falls	6/25	1		-	
103	1	Forney Creek at Sliding Falls	6/25	1		-	

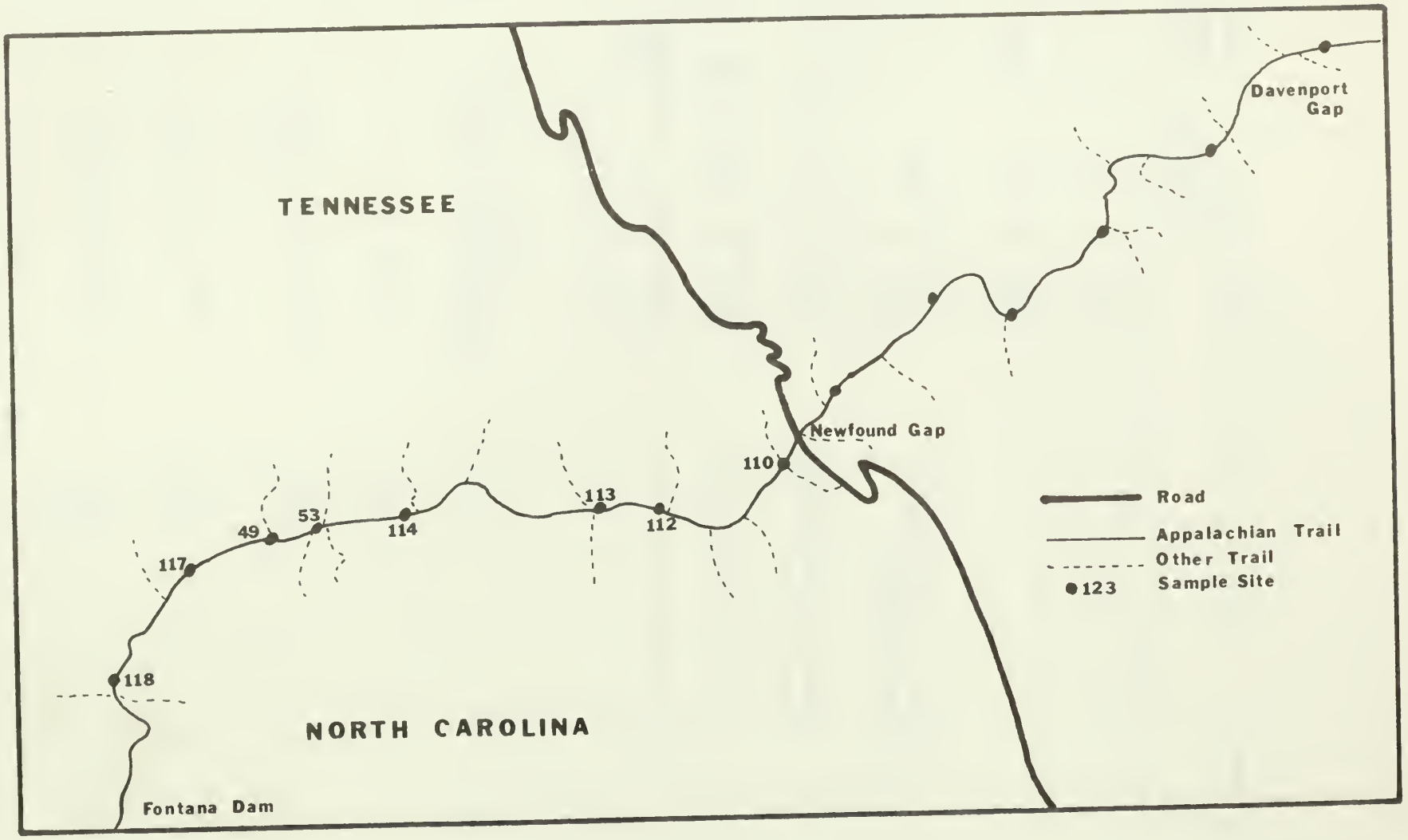

Tennessee
North Carolina
113
112
110
Clingmans Dome
91
Oconaluftee River
88
89
90
Smokemont
96
97
98
99
Deep Creek
92
102
103
Forney Creek
Noland Creek
100
93
101
95
94
Cherokee
Fontana Lake
Bryson City
Road
Park Boundary
Stream
Trail
78 Sample Site
Lake

APPALACHIAN TRAIL

This includes the water sources, all springs, for all the shelters on the Appalachian Trail within the park. These springs are all quite heavily used, both by people and wildlife.

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
104	3	Davenport Gap Shelter	6/26	0	0	343	559
			7/8	0	0	15	16
105	3	Cosby Knob Shelter	6/25	0	0	8	4
			7/8	0	0	1	1
106	4	Tricorner Knob Shelter	6/25	7	10	25	21
			7/7	171	173	THTC	
107	4	Pecks Corner Shelter	6/24	4	7	4	8
			7/7	0	0	1	0
108	3	False Gap Shelter	7/6	0	0	1	1
109	3	Icewater Spring Shelter	6/24	0	1	71	17
109	3	Icewater Spring Shelter	6/24	0	1	71	17
			7/6	0	0	0	½
110	3	Mt. Collins Shelter	7/31	0		1	
			8/1	1		-	
112	4	Double Springs Shelter Tennessee side	5/31	0		-	
			7/10	27	26	180	174
			8/1	2		0	
	4	Double Springs North Carolina side	5/31	0		1	
			6/27	0	0	0	0
			7/10	28	70	130	67
113	3	Silers Bald Shelter	5/31	0		0	
			6/27	0	0	183	288
			7/10	0	0	0	0
			8/1	0		-	

Site	Source	Sample Location	Date	Fecal Coliform per 100 ml.		Fecal Strep per 100 ml.	
114	3	Derrick Knob Shelter	6/28	0	0	3	
			7/10	1	0	1	15
55	4	Spence Field Shelter	6/27	2	4	7	9
			6/28	0	0	183	33
			7/11	1	0	13	33
			8/4	2		-	
49	4	Russell Field Shelter Upper Source	6/27	39	62	1	0
			6/28	6	4	3	2
			8/4	1		-	
	3	Russell Field Shelter Lower Source	7/11	2	3	10	6
			8/4	1		-	
117	3	Mollies Ridge Shelter	6/29	0	0	17	-
			7/11	0	0	47	344
118	4	Birch Spring Gap Shelter	6/29	14		THTC	
			7/12	7	6	178	220


TENNESSEE
NORTH CAROLINA
Davenport Gap
Newfound Gap
Fontana Dam
110
112
113
114
53
49
117
118
Road
Appalachian Trail
Other Trail
123 Sample Site

PREVIOUS DATA

The following data was collected during preliminary work conducted by Dr. Susan Bratton during January and February of 1976. No holding media was used and samples were kept for substantial periods before being processed. Samples were only tested for fecal coliform. The investigators suspected that the low counts for many of the samples were due to slow processing. These findings resulted in a study of techniques for preventing die-off of bacteria when sampling was done a great distance from the trail (See the data for study of die-off rates in the following section). This data was not used on this study. Note, however, the winter data from Spence Field.

Sample No.	Source of Sample	Fecal Coliform per 100 ml.
1	Rough Creek, Campsite #24	0
2	Rough Creek 30m above site	0
3	Rough Creek 10m below site	0
4	Rough Creek 30m below site	0
5	Rough Creek 30m below site, 10 ml sample	0
6	5m above ford on Parson's Branch Road	0
7	Water source above trail to Sheep Pen Gap	0
8	Water source above trail to Sheep Pen Gap	0
9	Moore Spring at Source	0

Sample No.	Source of Sample	Fecal Coliform per 100 ml.
10	Moore Spring 10m below source	0
11	Moore Spring 30m below source	0
12	Above first foot bridge on trail down Gregory Ridge	1
13	Campsite #12, Stream at site	6
14	Campsite #12, 30m above site	3
15	Campsite #12, 10m below site	6
16	Campsite #12, 30m below site	10
17	Campsite #53, 30m above site	0
18	Campsite #53, stream at site	0
19	Campsite 53, stream 10m below site	0
20	Campsite #53, stream 30m below site	0
21	Campsite #54, stream 30m above site	0
22	Campsite #54, stream at site	5
23	Campsite #54, stream 10m below site	1
24	Campsite #54, stream 30m below site	1
25	Campsite #55, stream 30m above site	1
26	Campsite #55, stream at site	0
27	Campsite 55, stream 10m below site	0
28	Campsite #55, stream 30m below site	1
29	Campsite #56, stream, 30m above site	3
30	Campsite #56, stream at site	0
31	Campsite #56, stream 10m below site	0

Sample No.	Source of Sample	Fecal Coliform per 100 ml.
32	Campsite #57, stream 30m above site	0
33	Campsite #57, stream at site	0
34	Campsite #57, stream 10m below site	0
35	Campsite #58, stream at site	0
36	Campsite #58, stream 10m below site	0
37	Campsite #59, stream at site	2
38	Campsite #59, stream 10m below site	0
39	Campsite 60, stream at site	0
40	Campsite #60, stream 10m below site	0
41	Spring above trail to Spence Field	0
42	Campsite #9, stream at site	0
43	Campsite #9, stream 30m above site	0
44	Campsite #9, stream 30m below site	0
45	Spring at Spence Field Shelter	129
46	Spring 10m below source, Spence Field	160
47	Drainage 30m below privy, Spence Field	0
48	Spring near Little Bald	0
49	Spring near Little Bald 30m below source	0
50	Russell Field Shelter Spring at source	0
51	Russell Field Shelter Spring, 30m below source	0
52	Russell Field Shelter Spring, below trail	0

Sample No.	Source of Sample	Fecal Coliform per 100 ml.
53	Campsite #10, stream at site	0
54	Campsite #10, stream 10m below site	0
55	Campsite #8 (Horse camp), stream 50m above site	2
56	Campsite #8, stream at site	2
57	Campsite #8, stream as enters picnic area	0
58	Little River at Elkmont - Total Coliforms	52
59	Little River at Elkmont - Fecal Coliforms	1
60	Cosby Creek at Ranger Station - Total Coliforms	0
61	Cosby Creek at Ranger Station - Fecal Coliforms	0
62	Big Creek at Ranger Station - Total Coliforms	0
63	Big Creek at Ranger Station - Fecal Coliforms	0
64	Greenbrier Creek at Ranger Station - Total Coliforms	0
65	Greenbrier Creek at Ranger Station - Fecal Coliforms	1

DATA FOR STUDY OF DIE-OFF RATES

Samples were all taken from the Little Pigeon River below Gatlinburg at the same time. There were filtered and incubated at various times after that. Samples were run both for water held at room temperature and for refrigerated water, or were kept in holding media at room temperature. Time refers to the interval between sampling and filtration.

Time	Refrigerated Sample				Room Temperature			
(hours)	Coliform		Streptococcus		Coliform		Streptococcus	
0	6969	7000	5280	6340	6960	7000	5280	6340
4	5440	5680	5600	5500	8100	7500	6000	5720
17	7300	7080	5700	5800	8840	9600	5360	5300
28	7400	6820	6060	6420	8680	8800	3200	3500
41	6720	6520	5040	5140	-	8000	3820	3260
52	6840	4800	5480	6780	4000	4620	1500	1760
76	5100	5180	5600	5200	380	220	200	280
100	6360	7080	4540	-	160	100	80	100
124	5000	6400	-	-	90	90	20	30
144	5800	5900	7900	5100	170	150	21	30

HOLDING MEDIA TEST

Time	Coliform		Streptococcus	
0	460	420	180	170
24	480	660	210	140
72	270	590	160	140

APPENDIX II

The following is an example of a training handout on water quality, for distribution to park employees.

GUIDELINES FOR PARK PERSONNEL
VISITOR INFORMATION AND WATER QUALITY
OCTOBER 1976

Although water quality in the backcountry is generally quite good and tests indicate that fecal coliform counts are quite low, individual springs and streams occasionally are contaminated by fecal material.* Springs (including those at the Appalachian Trail shelters) may be contaminated by surface water. Human or wildlife use may greatly increase the levels of bacteria present in small streams.

It is important that park staff who have frequent contact with visitors, provide correct information about park water quality. Some visitors may choose poor sources for water, may not purify drinking water, or may contaminate water themselves. Increased visitor awareness is the best way of preventing health problems in the backcountry.

---

*Copies of the Preliminary Backcountry Water Quality Survey are available from Uplands Lab or from the Park Library.

The following outline illustrates the major principles of backcountry water use. The outline is followed by a series of questions, like those commonly asked by visitors, and includes sample responses.

I. No backcountry water sources are approved drinking water sources. Any approved drinking water source must be developed, protected properly and tested regularly and must consistently produce coliform counts of zero (no evidence of fecal or surface water contamination). There are also limits on turbidity and chemical concentrations. The National Park Service does not test backcountry water sources regularly and most have never been tested. In a recent survey many of the springs tested gave positive coliform counts.

Because the National Park Service does not regularly test backcountry water sources, they cannot be maintained with walls, pipes or holding basins that give the visitor the impression that the water is safe to drink. Any efforts to "maintain" a water source in the park need to be cleared by the sanitarian.

II. Park staff should be careful about giving visitors the impression park water is safe to drink. If an interpretive program extolls the values of "clear, cool mountain streams" the visitors should be reminded to purify water before drinking. Park staff

in uniform, or leading walks, etc., should not drink unpurified water in front of visitors. Under no circumstances should visitors be told that backcountry water is "fine" or "safe to drink." The National Park Service could face a tort claim if a staff member told visitors to drink the water, and the visitors took water from a contaminated source and became seriously ill. A disease outbreak is not a likely event, but it could happen.

III. Visitors frequently assume a spring near a maintained shelter or campsite must be "safe." This is not necessarily true. Campsites are not only subject to intense human use, and therefore, liable to contamination by careless hikers, but springs also attract wildlife, which are likely to be active in or around the spring or creek. Heavy human use is not an indication that a spring is good; in fact, it is an indication that one should be more careful because of increased chances of human contamination.

IV. In some cases hikers may be adding to the water quality problems. Reminders that human wastes should be deposited away from water sources and that such wastes should be buried are appropriate for novice hikers. They should also be informed that leaving garbage around the campsite attracts wildlife, which may contaminate the water source.

V. The quality of the water in the streams in Cades Cove and Abrams Creek is lower than that of other streams in the park. Hikers traveling along Abrams Creek should obtain water from tributaries whenever possible and should be reminded to purify all water taken anywhere in the park. Abrams Creek also carries a heavy load of silt and other suspended matter, which may effect the quality of water for drinking.

VI. The best sources for obtaining water (to be purified) are free flowing springs or large streams with little or no turbidity to indicate recent runoff (both located above campsites or trails). Low yield springs, springs with surface drainage and small streams should be avoided. No backcountry site should ever be considered absolutely safe.

ANSWERS TO SOME COMMON QUESTIONS ABOUT

WATER QUALITY IN THE PARK:

1) Is it safe to drink the water?

You should always treat drinking water taken from a backcountry source. Although most of the water sources in the park are fairly clean, backcountry water is occasionally contaminated by people or wildlife.

2) How do you purify drinking water?

Most bacteria may be killed by boiling but many hikers find chemical purifiers such as Halazone or chlorine more convenient. You can purchase water purification tablets at most drug stores or use two drops of 4-6% chlorine (chlorine bleach will do) per quart of water and leave it to stand for 30 minutes. If the water is turbid use four drops of chlorine.

3) Is there any way to tell if a drinking water source is pure?

There is no way to tell if a water source is contaminated without testing it in a laboratory. Streams which are muddy should be avoided because the silt and other suspended material interferes with disinfection.

4) Is the water in the backcountry ever tested?

Yes, in a few cases the National Park Service has tested some springs and streams for contamination. None of the water sources are checked regularly, however, and none should be considered maintained drinking water sources.

5) Is the water in the park safe for swimming?

All the streams in the Great Smoky Mountains National Park are suitable for swimming. The stream which runs along the Spur between Gatlinburg and Pigeon Forge is contaminated by sewage effluent from Gatlinburg and is posted as contaminated.

Should tests indicate a water source is consistently contaminated and does not meet state standards for recreational water, the National Park Service will post roads or trails near the streams until the problem has been brought under control.

6) Is backcountry water suitable for washing?

Most water is suitable for washing, but we suggest that you rinse dishes and eating utensils with boiling water, and that untreated spring or stream water not be used for cleaning open wounds, broken blisters, etc. Please do not wash dishes, clothes or yourself in a spring or stream near a campsite, or put soap or food wastes into water sources.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.